

## PLASTIC CELL FILLED CONCRETE ROAD: A REVIEW

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### **Abstract**

*The aim is to carry out a review of Plastic Cell-Filled block pavement by the study of previous experimental studies carried to satisfy the need of sustainable all weather roads with accessible riding quality in rural areas with satisfactory life span and maintenance cost. As Under the centrally sponsored scheme PMGSY various emerging new trends and advanced materials and methods of construction are being adopted. Hence it becomes necessary to study the effectiveness, functional and structural evaluation of Plastic cell-filled concrete block pavements (PCCBP). The main role of the present work is to study the pavement performance evaluation of cell-filled concrete block pavement. The pioneer of cell-filled pavement is Prof.Visser1994,1999;visser and hall,1999,2003). This pavement can also be known as Flexible-rigid cast-in-situ block pavement. A Low density poly-ethylene (LDPE) plastic sheet of thickness 0.49 mm is used to construct the cell-filled pavements. In order to evaluate the structural performance of the test sections with traffic passes, daily traffic volume data, performance criterion to limit rutting under traffic repetitions. Non-destructive structural evaluation using falling weight deflectometer by doing back calculation analytically based on genetic algorithm and NDT can be done by Rebound Hammer Test. Destructive test such as cone penetration to determine the compressive strength. The evaluation of distress has been done considering pavement condition index(PCI) and found to be satisfactory as per PCI Rating.*

**Keywords:** *Plastic cell-filled block pavement, sustainable, low density polyethylene, structural evaluation, Pavement condition index.*

## INTRODUCTION

In India, there are about more than 6 lakhs villages located in different terrain conditions ,e.g. plains, hilly, and mountainous region, deserts, swamps, coastal region etc. Providing good network of all-weather sustainable roads with accessible riding quality is very essential for social, educational and economical development of any country. The Employment opportunities and basic amenities such as health, education, cannot reach rural masses without a system of good road network [1-3]

Rural roads are given priority under a centrally sponsored scheme named PMGSY launched on 25 December 2000. Under the National Rural Road Development Authority (NNRDA) in Ministry of Rural Development. Although a lot of efforts were taken successful implementation of this scheme. Not more than 50% of the 6 lakh villages were availed with all-weather roads. In rural areas these roads were not considered as engineering structures and sub-standard practices were carried out during the construction of this pavements . Many of the technical aspects of pavement design such as adequate compaction of subgrade, drainage, pavement thickness etc [4-8].

In recent times the reliance is shifting more on rigid pavements because of its low maintenance cost, long service life and the smoother riding surface .

Though it has high initial cost, but can also fail due to various causes such as day and night variations in warping stresses, seasonal changes in the modulus of sub-grade reaction etc. Thus, as an alternative for concrete pavements for better structural performance and low maintenance cost, an advanced pavement technology called Plastic cell-filled concrete block pavement (PCCBP) was developed in South Africa[. -Test results have been studied for pavement distress evaluation and non destructive tests were carried on a certain test section.

## NEED OF STUDY

- To check the reliability and feasibility of the advanced technique of plastic cell-filled block pavement.
- To evaluate functional and structural parameters of pavement distress.
- To study pavement deterioration modeling in terms of pavement condition index (PCI).
- Find economical construction of rural roads using PCCBP.

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## LITERATURE REVIEW

Yendrembam Arunkumar Singh et.al (2011) conducted a study on Plastic Cell-Filled Block Pavement for low volume rural roads. He carried on various tests of pavement distress evaluation and economical consideration by construction a test section [9-12]. The conclusion drawn were that PCCBP can be economical alternative to conventional rigid pavement and the distress of pavement was within permissible limit and rated good as per pavement condition index(PCI).

Surender Singh, Dr.S.N.Sachdeva et.al (2015) conducted a study on thickness Requirement of a Rigid Pavement with varying Conditions of Sub-Grade, Sub-Base and Shoulders and concluded that subgrade strength has insignificant effect on the slab thickness for all types of subbase materials.

Prof. Shrikant M. Harle, K. D. Dagwal et.al (2016) carried a review study on plastic cell-filled block pavement by constructing a test section and concluded that PCCBP is economical than flexible pavement considering over all cost of construction and maintenance and found the pavement to be good as per PCI rating, the roughness due to cells make little difference in riding quality.

Subrat Roy, K.S. Reddy and B. B. Pandey .et al.(2005) conducted an Investigation on Cell-filled Pavement by constructing a test section and heavy vehicular traffic of nearly 400 trucks daily were passed from it. The main conclusion drawn was that the pavement is only suitable for low volume traffic and not suitable for heavy load traffic and foundation failure of shear occurred.

Yendrembam Arunkumar Singh, Teiborlang Lyngdoh Ryntathiang , Konjengbam Darunkumar Singh .et.al.(2012) conducted a study on Structural Performance of Plastic Cell filled Concrete Block Pavement for Low Volume Roads and found that the elastic modulii of pavement increases with considerable increase in thickness of pavement.

Hariprasad. M, H. S. Prakash Kumar, Purushothama Das Heggade, Dr. B. V. Kiran Kumar(et.al) conducted a study on cell-filled concrete roads by a construction test sections of various thickness in a place in Karnataka and observed that pavement can be recommended for weak base and sub-base layers instead of flexible pavement, since it showed resistance to structural durability [13-15].

W. K. Mampearachchi, A. Senadeera (et.al) 2014 conducted a study on pattern of laying of block pavements for medium and heavy traffic and found that both stretcher bond and herring bond both show satisfactory results under Benkelman Beam Deflectometer (BBD) studies and concluded though both show similar performance an ideal block laying pattern was not found in the study.

Animesh Das(et.al)2008carried a study on Interpretation of Falling Weight Deflectometer data and proposed its suitability for pavement evaluation and concluded that FWD (impulse loading method) efficiently used for estimation of in-situ stiffness values and thickness of the pavement layers.

Halil Murat Algin (et.al.) 2007 conducted a study on interlock mechanism of block pavement and studied various reasons pavement failure such as soil failure beneath pavement and concluded that chamfered block are preferred over non-chamfered blocks due to edge restraint.

Manik Barman, B.B.Pandey (et.al.)2008 conducted a study on advance method of pavement evaluation of rigid pavement using FWD and BACKRIGID calculations and concluded that the output of the

developed model can provide input for mechanistic design of overlay for the design of overlay at highways and airports.

S.Nazarian, D.Yuan (et.al.)1999 conducted a study on Structural Field testing of Flexible Pavement Layers and studied elastic moduli response of layers in pavement and presented an approach for systematic assessment of layers, concluded that Poisson's ratio of each layer should be considered along with the elastic moduli.

Ansgar Emersleben, Norbert Meyer (et.al.)2008 carried a study on the Use Of Geocells In Road Constructions Over Soft Soil the layers were evaluated under FWD testing and concluded that layers with geo-cell reinforcement showed lesser valued of vertical stress deflections.

M.Y.Darestani, David P Thambiratnam (et.al.)2006 carried a Study on Structural Response of Rigid Pavements under Moving Truck Load with dynamic analysis and concluded that the base deflection in Joint Reinforced Concrete Pavement decreases with reinforcement was located close to bottom surface layer of the concrete base.

Shahbaz Khan, M.N.Nagabhushana(et.al)2013 studied failure of Rutting in Flexible Pavement

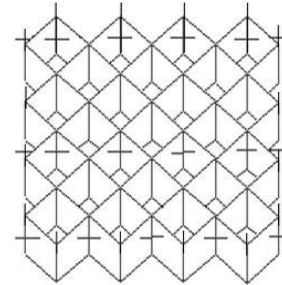
and presented an approach of evaluation with Accelerated Pavement Testing Facility and concluded that rain has significant effect on the performance by higher rate of increment in rutting of the test section and also the change in air voids were found less for bituminous concrete than dense bituminous concrete.

Francesca Russo, Raffaele Mauro (et.al.)2012 carried a study on *Rural Highway Design Consistency Evaluation Model*” they conducted the study based on two criteria such as average weighted speed, and standard deviation of operating speeds and concluded that the behavior of road under different speed varies with length of road.

## PLASTIC-CELL FILLED BLOCK PAVEMENTS

The concept of cell-filled pavement was developed in South Africa (Visser, 1994, 1999; Visser and Hall, 1999, 2003) it consists of plastic cells made of low density polyethylene (LDPE) of 200  $\mu$  or 0.49mm thickness. These cells are filled with cement concrete and well compacted over granular sub-base or water bound macadam surface . As each cell acts a block these are also known as flexible-rigid cast-in situ block pavement.

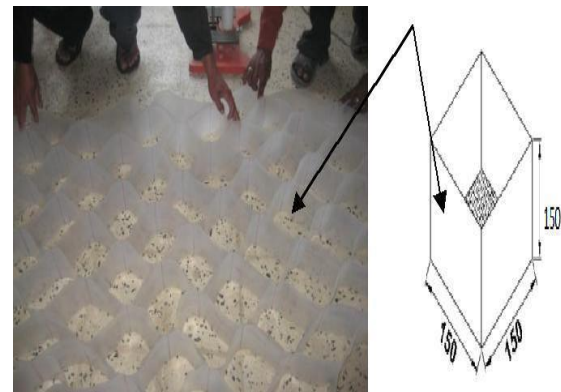
For Design of such pavements, vertical sub-grade strain should be the main performance criterion to limit rutting under traffic repetitions.



**Fig.1** Stretched plastic-cell reinforcement(.Dagwal et.al)

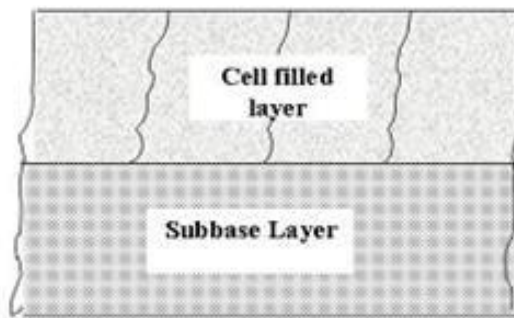
The above figure 1 shows the schematic arrangement of the formwork of cells stretched along the carriage way and tensioned by using steel pegs.

Each block consists of size 150×150mm and depth 100mm. The plastic strips are formed by cutting of plastic in to 150mm size. Strips are marked at 30 cm interval. So that on straightening it should form the diamond of size 0.212m\*0.212m.



**Fig 2** Layout of the plastic cells and size of each block.( Dagwal et.al.)

During Compaction, cell walls get deformed and provide interlocking among the blocks as shown fig 3 These pavements can also be known flexible-rigid / cast-in-situ block pavement.



**Fig 3** Plastic cell after compaction  
(dagwal et.al)

The cell walls get deformed after compaction and the plastic cells induce elastic behavior in pavement and thus it can be called as flexible-rigid pavement.

#### V. MATERIALS

#### Low density Polyethylene

For the construction of PCCBP Low density polyethylene (LDPE) plastic cells are made of low density polyethylene which is having around 200 $\mu$  or 0.49 mm. For making the plastic cell the plastic sheet is cut into 150 $\times$ 150mm and depth of 100mm. The LDPE cells are joined by paddled sewing machine or either by heat sealing.

#### Coarse Aggregate

Locally available coarse aggregate of size 20 mm & 10 mm are used for laying of sub-base & sub grade layers. Some standard tests were performed previously on the aggregates for determination of engineering properties of the coarse aggregate and values are thus obtained moreover the mean values of test are taken from literature review as shown below.

**Table 1** Test conducted on Aggregates used in PCCBP(et.al.Dagwal,Y Singh)

Sr .No	Name of test	Test 1	Test 2	Test 3
1	Specific Gravity	2.7	2.68	2.65
2	Impact value	5.60%	5.54%	5.80%
3	Abrasion resistance	25.68%	26.8%	25.62%

#### Cement

The cement for the construction of PCCBP test sections should be procured in a single consignment and stored properly from moisture and damp conditions. Ordinary

Portland cement (OPC) of grade 53 can be used for casting concrete blocks. The standard consistency of the OPC cement should be 30-35mm. The initial and the final setting time should be nearly equal to



30 and 600 minutes respectively. The standard tests such soundness, fineness test should be carried on the cement which is used for the construction of cell-filled block pavement.

### **Sand/ Fine aggregate**

Locally available fine aggregate or river sand within permissible limits of bulk density can be used if sand is not available in much quantity then stone dust from quarry can be used as replacement of sand.

### **Soil**

IS 2720 has laid some of the criterion in terms of specific gravity plastic limit and liquid limit. The soil used for backfilling of the pavement and preparation sub-base required beneath the pavement layers.

## **METHODOLOGY**

### **Construction of test section of PCCBP**

#### ***Mix Composition and Strength of Cement Concrete***

A minimum compressive strength of 30 MPa is desirable for concrete block pavement for village roads (MORD 2004). Cement, sand and coarse aggregates were taken in the proportion of 1:1.25:2.5 by volume as weigh batching is found inconvenient in villages hence volume batching is generally preferred for village

road projects. Field moisture is convenient for village road projects. Field moisture contents of sand and coarse aggregates were determined to be 3 and 1%, respectively. The optimum moisture content for concrete mix was obtained as 5% by weight of the total weight of coarse aggregates, fine aggregates and cement (MORD 2004). Concrete cubes of dimension 150mm x 150mm x 150mm in size (IS10086:1982) were casted. Steel cubical moulds 150 x 150 x 150 mm in size (BIS 1959) were used for determining the strength of mix proportions. The crushed aggregates of nominal sizes such as 26.5 and 22.4 mm, 22.4 mm were used in addition to single size pit run gravel was also considered to explore its use for rural connectivity at a lower cost since the material is cheap and easily available in many adjoining areas. Cubical moulds were filled with single size aggregates, and cement-sand mortar was vibrated until all voids were filled. Excess mortar was removed by means of a straight edge. The cube strength was determined after 7 days of curing in water. The average value of 7-day compressive strength was obtained as 38.6 MPa.

### **Construction of Test Section**

A test section with sub-base and surface layers (cell-filled) was constructed. The

length and width of the section are 10 m and 4 m, respectively. From studies of (et.al)Y Singh several test sections of varying thickness were constructed of size 2.7\*5.3 m.

### Excavation

The excavation of the existing pavement for the construction was done using an earth excavator. The upper layers of the existing pavement were removed and a trench measuring 15 m in length and 7 m in width and approximately 450 mm depth was excavated (Figure 4) till sub-grade soil layer. After excavation the loose materials were properly removed and the natural soil was properly levelled.



*Fig. 4 Excavation of existing pavement. (Y.A.Singh et.al)*

### Preparation of Sub-grade soil

The trench was backfilled with selected soil. Laboratory compaction test was conducted to determine optimum moisture content (OMC) and maximum dry density

(MDD) of the soil. Compaction was done at the optimum moisture content (~12%) using a 100 KN three wheeled roller in three layers of 100 mm each, maintaining cross and longitudinal slopes. After compaction the surface was levelled manually to bring the surface to the required profile.



*Fig.5 Laying and Compaction of sub-grade. (Y.A.Singh et.al)*

The field density and the moisture content of the compacted sub-grade soil was determined by core cutter method and were found to be 1880 Kg/m<sup>3</sup> and ~12 % respectively. The percentage field compaction was found to be ~98% of the standard laboratory compaction value.

### Water Bound Macadam (WBM) Coarse

In the earlier work 100 mm thick WBM sub-base course was provided above the prepared sub-grade soil layer. Crushed stone aggregates and screenings conforming to Grading 1 and Grading A respectively as prescribed by MORTH (2001) were used for WBM course. The



materials were manually placed and spread uniformly over the prepared sub-grade soil. Laying and compaction (Figures 6) was done as per MORTH (2001). Rolling with copiously sprinkling of water and sweeping with brooms for WBM was continued until the slurry that is formed will, after filling the voids between aggregates form a wave ahead of the moving roller indicating that the voids are fully filled and the layer is properly compacted (CPWD, 1996).



**Fig.6** Laying and Compaction of sub-grade.(Y.A.Singh et.al)



**Fig.7** Formwork of plastic-cells.(Y.A.Singh et.al)

### Fixing of Formwork

After the leveling with the roller, form work is placed on site. Form work is so

placed that the inner dimension should be 4m x 10m. Inside this form work the placing of plastic cells and concreting is going to be done.

### Laying and Concreting of Plastic cells

After fixing the form work plastic of section 4m x 1m is laid. Such 10 sections are prepared for 10m x 4m road. These plastic sections are stretched by the help of steel bars. After stretching the diamond shaped box of size 0.212m x 0.212m should be formed. At the joining of two sections steel bars are provided so that there should be proper bonding between two sections.

Concreting is done with the help of RMC. Direct pouring of concrete on plastic and labourers are used to carry out filling of each section. After completion of filling each section proper slope is given to the road and finishing is carried out. While pouring the cement proper is taken that it should not get set.



**Fig. 8** Laying of Concrete.(Dagwal et al)



**Fig.9** *Compaction of Concrete. .(Dagwal et al)*

### **Curing of the PCCBP test section**

Casting of the whole test section can complete in a single day and then allow the concrete to set overnight. Longer lane closure to ensure curing is a criticism for concrete pavement. After removing water, clean the pavement properly and collect the initial surface deflection data of the test sections (using FWD) and non-destructive test such as rebound hammer test, pulse velocity test benkelmen beam deflectometer etc. before opening to the regular traffic. Core samples collected from the test sections will show that the compaction is proper and the thickness of each section is maintained properly. The PCCBP test section is ready to open to normal traffic after 25 days from the day of casting.

### **Pavement Distress Evaluation**

#### **Traffic survey**

In order to evaluate the structural performance of the test sections with

traffic passes, daily traffic volume data was collected. The design traffic is ranging from 1 MSA -150 MSA and the traffic growth is considered as 7.5% as per IRC 58. Only axles with weight of 3 tonnes and above are considered to have an effect on pavement performance.

### **Pavement Condition Survey**

A survey of the surface of existing pavement after passage of traffic is collected so that damage on the pavement surface could be evaluated. The survey vehicle equipped with cameras, deterioration measuring instruments are employed.

### **Pavement distress**

External indicators of pavement deterioration caused by loading, environmental factors, construction deficiencies, or a combination thereof. Typical distresses are depressions, rutting and edge spalls of the test section.

### **Pavement condition index**

It is a numerical rating of the pavement condition that ranges from 0-100 with 0 being the worst condition and 100 being an ideal condition. It is an indicator of roughness and skid resistance and not of structural capacity.

### **Structural Evaluation**

The distress type identified in the present study which are similar to interlocking concrete block pavement manual (ICPI,2007).

### **Rutting**

Rutting is a permanent surface deformation that occurs along the wheel path. It is caused by settlement of the underlying layers viz., sub-grade or sub-base under traffic load. It can be located by visual assessment and is measured with a straight edge along wheel paths. After 62000 ESAL the rut depth was found to be nearly 15 mm reported by Y. kumar et.al.

**Faulting**It is the gap between two or more cells in PCCBP.

### **Edge spalls**

The Edge spalls occurs when there is a layer of concrete above the plastic cell top, and is generally due to bad workmanship with levels not flushed with the top of cells.

### **Scaling**

Scaling is the peeling of thin leveling cement mortar layer from the surface of pavement.

### **Exposed cells**

The plastic cell wall gets exposed due to the lose concrete is removed the plastic cells are exposed and subjected to wear under traffic.

### **Structural evaluation by Falling Weight Deflectometer Testing**

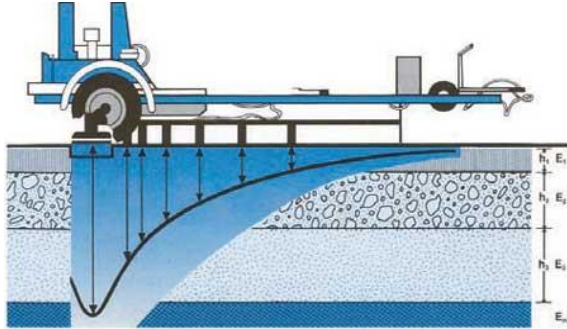
A custom fabricated Falling Weight Deflectometer (FWD), a non-destructive test (NDT) equipment which simulates the short duration loading of the fast moving wheel can be used to record the surface deflection data of the test pavement . BACKGA, a Genetic Algorithm (GA) based back calculation software can be used to calculate the pavement layer elastic moduli from the recorded surface deflection data. The purpose of FWD testing to asses the existing structural condition of the pavement and strength of the subgrade soils. In order to determine homogeneous sections of pavement and subgrade strength based upon deflection response.

### **Pavement Coring and Subgrade boring**

Identifying the location for coring and boring, the pavement material types, thickness and visual condition are to be determined. Usually borings to a depth of 4 feet should be performed.

### **Basin Testing Location**

FWD testing should be conducted in the wheel path closest to the nearest shoulder. This is to characterize the structural condition of pavement where damage due to truck loading should be greatest.



**Fig 10** Deflection Basin Collected with Falling Weight Deflectometer. .(Y.A.Singh et.al)

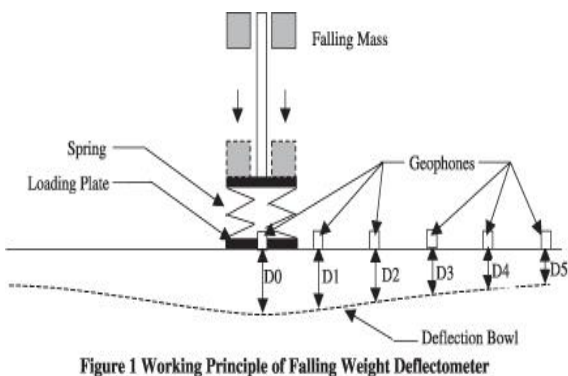


Figure 1 Working Principle of Falling Weight Deflectometer

**Fig.11** Working Principle of FWD.(Y.A.Singh et.al)

The sensor spacing to record pavement deflection data is dependent on pavement type as well as the testing purpose. For basin testing on flexible pavements the spacing should be 0in., 8in., 12in., 18in., 24in., 36in., 48 in., 60in., 72in., The no. drops are 14 at each test location.

The pavement temperature is recorded directly from temperature holes by an infrared thermometer which is fitted to the FWD if not then can be measured with a hand held thermometer. At joints it is used to assess the structural capacity of the pavement, estimate the Strength of sub-grade soils, assess load transfer at joints and detect voids at joints. The load plate is of 300mm diameter. The limit of impulse loading is from 20-100 KN. The analog input modules (AIM) are obtained from the recording of geophones and load cell. This data is analyzed in Labview software. The readings are calibrated and processed to determine load in Kilo-Newton and Millimeters.

**Cost Estimation(Y.singh et.al 2011 & K.Dagwal et.al.2016)**

#### **Flexible Pavement-**

- i. Construction of 150 mm thick granular Sub-base course=Rs169/m<sup>2</sup>
- ii. Providing and laying 150 WBM course =Rs 237/m<sup>2</sup>
- iii. Construction cost of 20mm thick hot mix asphalt layer =Rs 200/m<sup>2</sup>
- iv. Total cost=Rs 606/m<sup>2</sup>
- v. Routine Maintenance cost for 5 yrs =Rs45/m<sup>2</sup>
- vi. Renewal cost of flexible pavement after 5 yrs =Rs230/m<sup>2</sup>

### **Rigid pavement**

- i. Construction of 150mm WBM base course = Rs 203/m<sup>2</sup>
- ii. Construction of 220mm thick P.C.C. slab= Rs 1190/m<sup>2</sup>
- iii. Total cost =Rs 1393/m<sup>2</sup>
- iv. Routine maintenance cost for 5 yrs =Rs 16/m<sup>2</sup>
- v. Major repair cost =Rs 30/m<sup>2</sup>

### **Plastic-Cell Filled Concrete Block Pavement(PCCBP)**

- i. Cost of Moorum sub-base 150 mm thick (CBR>20) =Rs 60/m<sup>2</sup>
- ii. Cost of construction for 150 mm thick WBM =Rs 140/m<sup>2</sup>
- iii. Cost of plastic cell formwork=Rs 70/m<sup>2</sup> =Rs 70/m<sup>2</sup>
- iv. Cost of Cement concrete 100 mm thick=Rs550/m<sup>2</sup>
- v. Total=Rs820/m<sup>2</sup>
- vi. Routine maintenance cost for 5 yrs=Rs 16/m<sup>2</sup>
- vii. Major repair after 5 yrs=Rs26/m<sup>2</sup>

It can be seen from the above cost analysis of types of pavement that PCCBP is the most economical as compared to the conventional flexible and rigid pavement considering the initial cost, maintenance cost and life cycle cost.

### **DISCUSSIONS AND CONCLUSIONS**

- i. From the literature review, it has been observed that no attempt has been taken to study the effect of PCCBP thickness on the structural performance of pavements.
- ii. Very limited information is available on the variation of elastic modulus of blocks with block thickness.
- iii. No standards have been developed such as codes or manuals as yet for the construction and evaluation of pavement condition index for different types of distress that PCCBP may have. All work done in this respect is of experimental nature.
- iv. The construction and maintenance of PCCBP was found economical as compared to the conventional concrete and flexible pavement and also has satisfactory PCI.
- v. The structural evaluation of PCCBP shows that it is suitable for low volume village roads under limited axle load repetitions and not for very heavy traffic. The plastic-cell filled pavements can also be used as overlay over the existing pavement surface.

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